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Developing Metrics for LED System and Component Performance

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IES LIGHT MATTERS 07 INTEGRATING LIGHT INTO OUR ENVIRONMENTS

Acknowledgments

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Outline

- Introduction – LED technology
- Lighting – Choices of sources
- Performance Metrics
  - Source performance in different application environments
  - Fixture performance
    - Downlights
      - Proposed test method for evaluating directional light fixture
      - Validation of proposed test method
    - Under-cabinet light system
      - Proposed test method for evaluating under-cabinet light fixtures
      - Validation of proposed test method
- Summary

LED

- LEDs – Will soon be one of the light source choices for illumination applications.
- The potential for reduced energy use and lower maintenance costs are two key attributes of this rapidly evolving technology that have generated so much interest for its use.

Industry Trend

- Growing number of LEDs and LED fixtures
- LED performances have been steadily improving.
- Two potential illumination applications in the near term are:
  - Directional lighting (downlights)
  - Under-cabinet lighting

Lighting

- Presently, there are many light sources available to cater to lighting needs.
  - As an example, for downlights, end-users have many choices.

- Every light source is unique
  - Performance will vary depending on how a lamp is implemented into the lighting application

Quantifying Performance

- Metrics allow users to quantify and compare performances.

- To make meaningful comparisons between products, performance metrics developed for lighting applications must be technology-independent.

Metrics

- Presently, there are many metrics to quantify performance of light sources and fixtures.
  - Efficacy: Lumens per watt
  - Color: CRI, CCT, Chromaticity coordinates
  - Life
- Many specifications assume the performance of the lamp (or lamp-ballast combination), tested under an ideal environment, as the performance of the complete fixture.

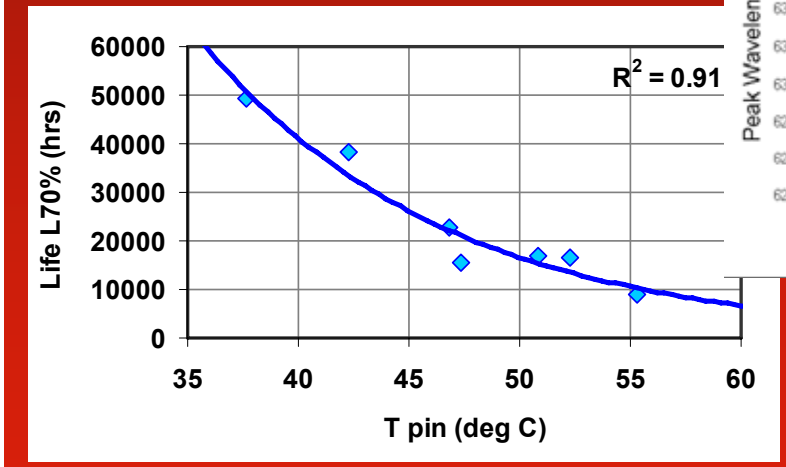
Application Environments

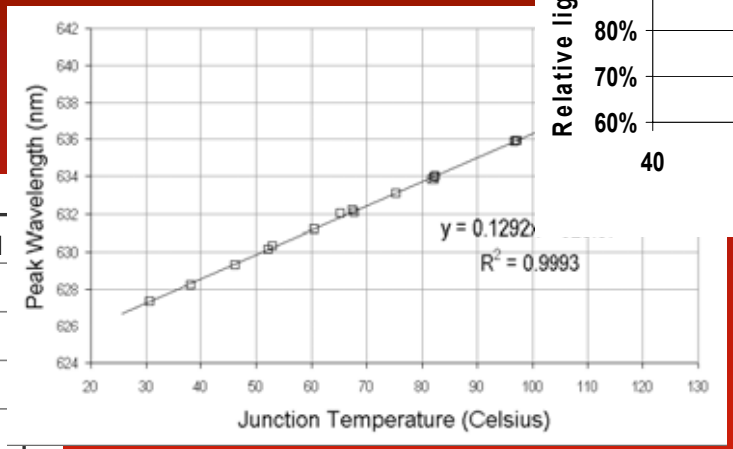
- Generally, light sources or fixtures operate in thermal environments such as:
  - Fully ventilated (e.g., track lighting, open-air)
  - Semi-ventilated (e.g., recessed downlight, Non-IC)
  - Enclosed (e.g., recessed downlight with ceiling insulation, IC)

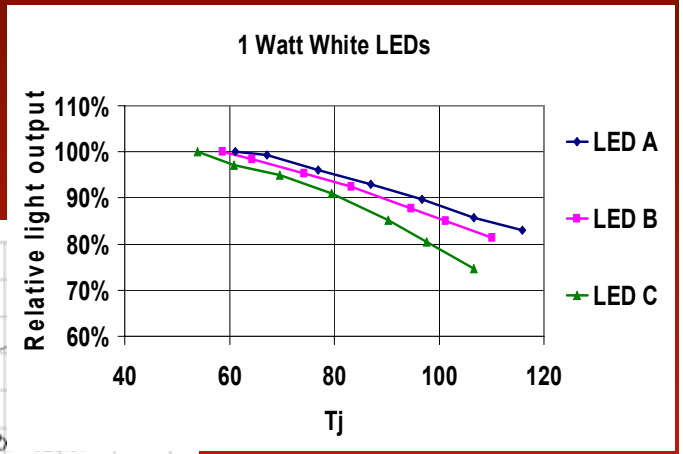
http://www.ylighting.com/linear-system.html

Impact of Heat on LEDs

- Heat at the junction affects the performance of LEDs.
  - Light output
  - Color
  - Life

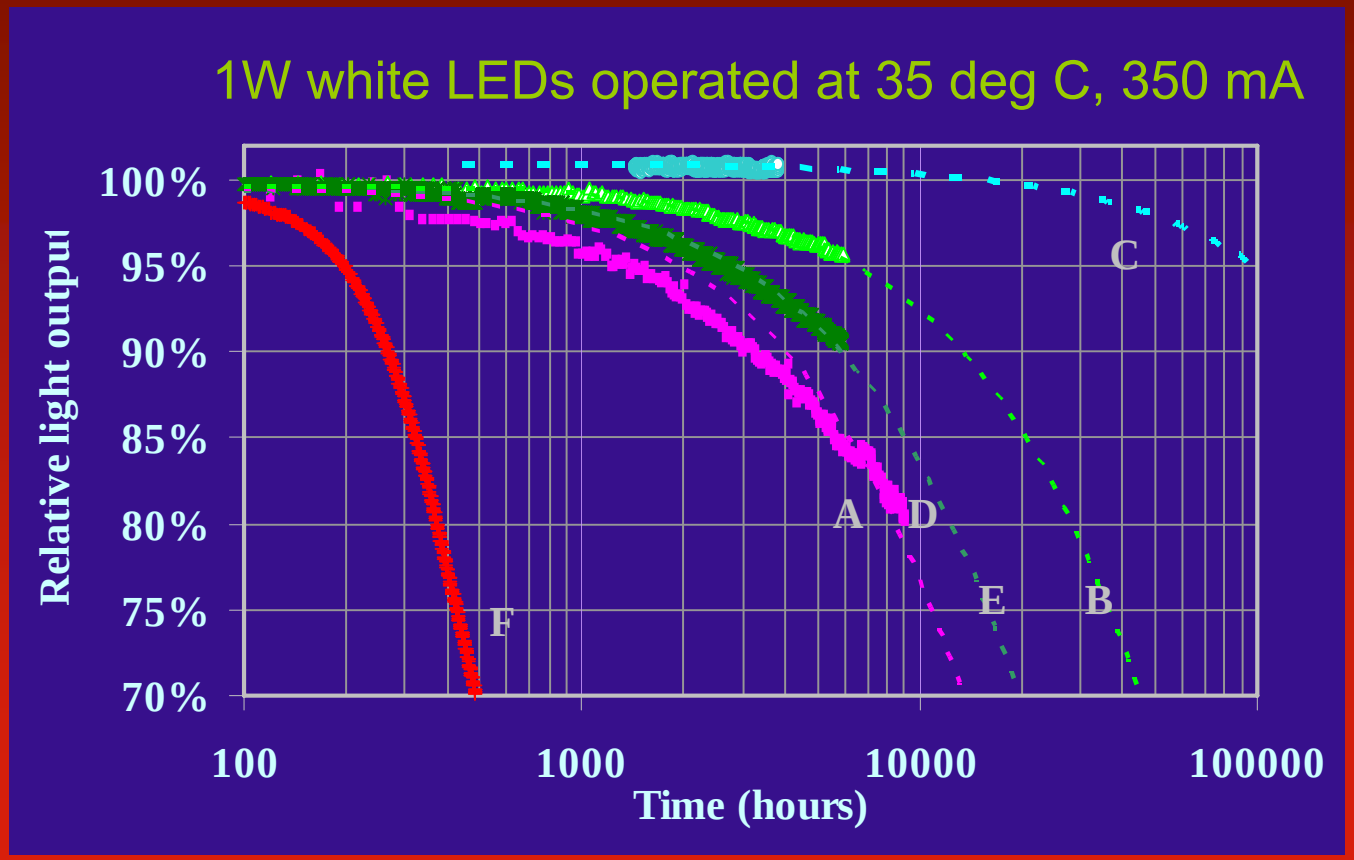






All products are not created the same

- Significant variation between products



System Performance

- Assuming the performance of the lamp or the complete system tested under an ideal environment as the performance of the system in any environment may not be correct for all technologies.

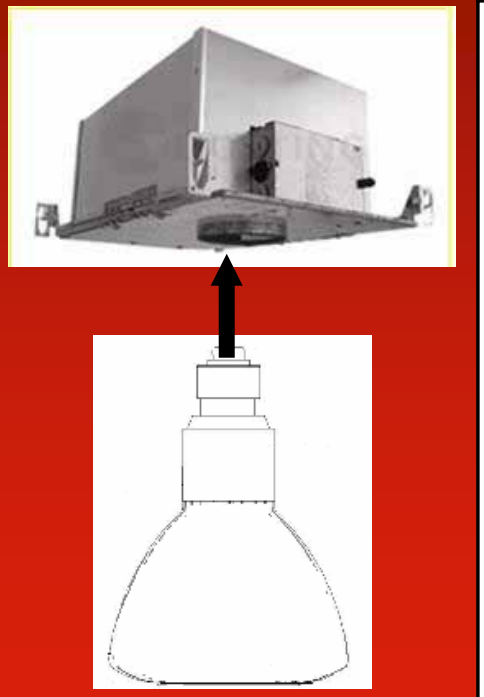
A sample commercial LED downlight

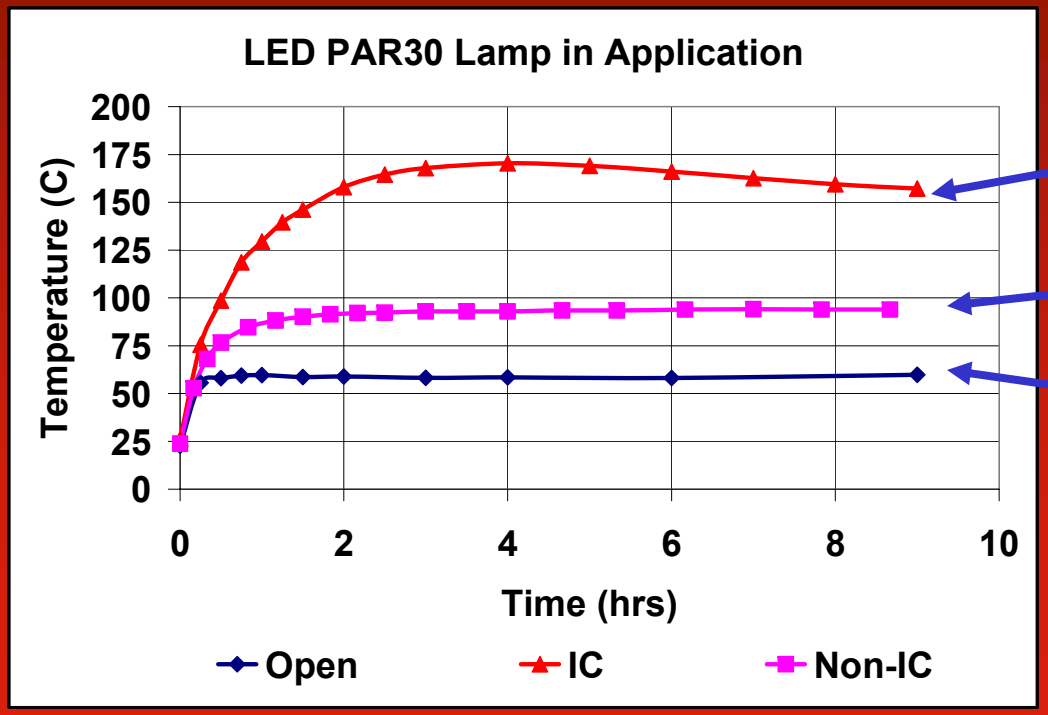
Condition	Power (W)	Flux (lm)	%Flux	Efficacy Lm/W	T_{pin} (deg C)	T_{amb} (deg C)
Open air	24.7	490	100%	20	72	23.5
IC	23.4	425	87%	18	116	23.6

- Heat affects the light output of LEDs.
- CFLs in downlights perform similarly, since their light output is also sensitive to heat.

LED PAR Lamp Performance

- The junction temperature of the LED array changes when the PAR lamp is used in the three different application conditions.





~ 160 deg C

~ 90 deg C

~ 60 deg C

Test Methods

- To obtain realistic performance data for a lighting system, the test environment must mimic the actual environment where it would be used.
- Question: How do we do that?
  - If we understand the factors that influence performance, then a test setup can be developed to test these fixtures.
- In this study, a test method is being proposed for evaluating directional light fixtures (like downlights) in conditions similar to their application.

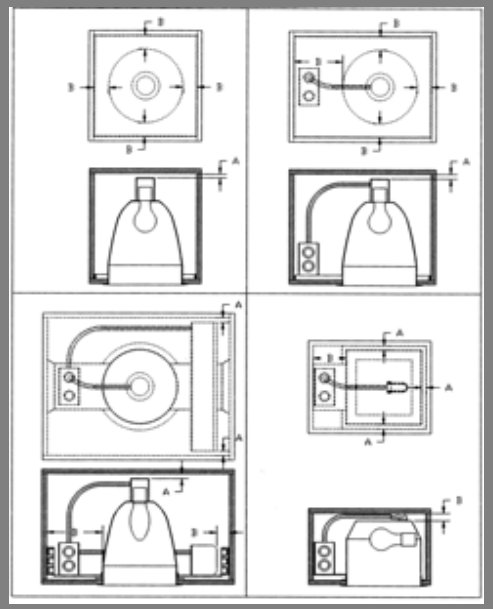
Proposed Method

- Test fixtures at temperatures similar to application conditions
  - Ventilated (open-air)
  - Semi-ventilated (non-IC)
  - Fully enclosed (IC)
- Measure temperature (Ts) when operating the fixture in a given condition
  - For LEDs, Ts is the board or pin temperature
- Operate fixture in the measurement setup at the same temperature (Ts) while gathering data

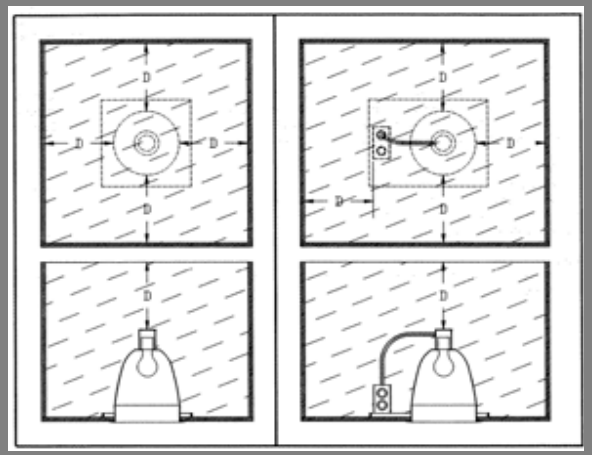
Test Setup

- Use of UL test setup to measure Ts
  - Open-air, Non-IC, and IC

Test boxes for temperature testing per UL 1598 guidelines



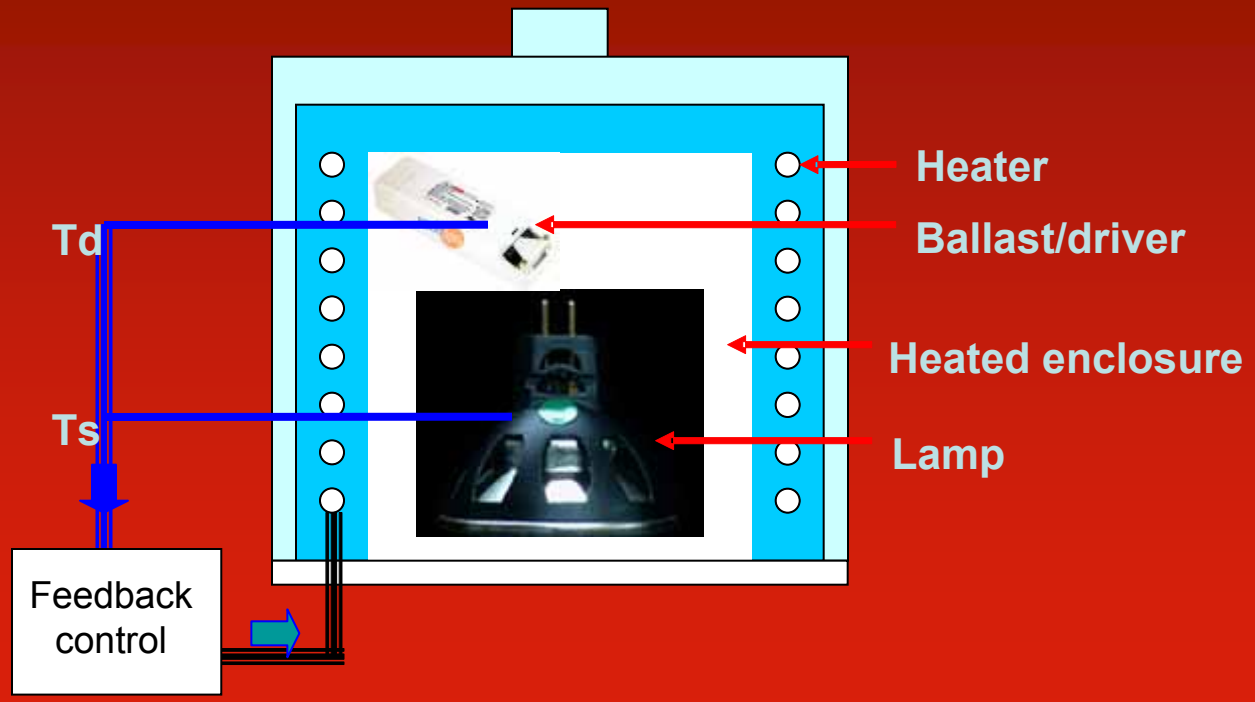
Non-IC Test Box



IC Test Box

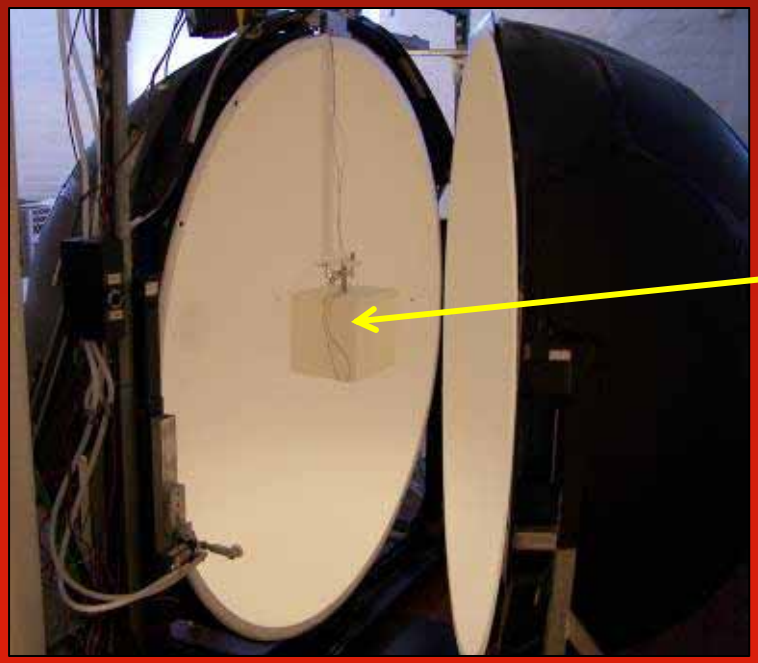
Sphere Measurements Test Setup

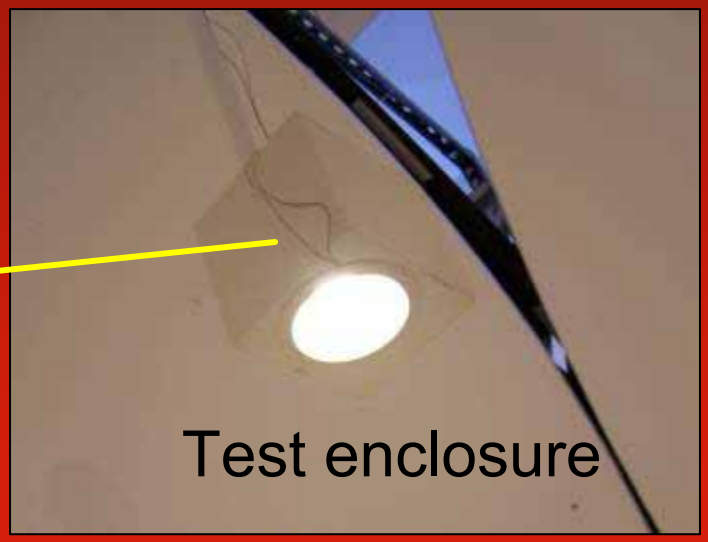
- Test enclosure includes heaters to maintain proper Ts operating temperature



Sphere Test

- Downlight inside the heated test enclosure
  - Test enclosure is similar to the enclosure used for testing directional lights in a sphere.



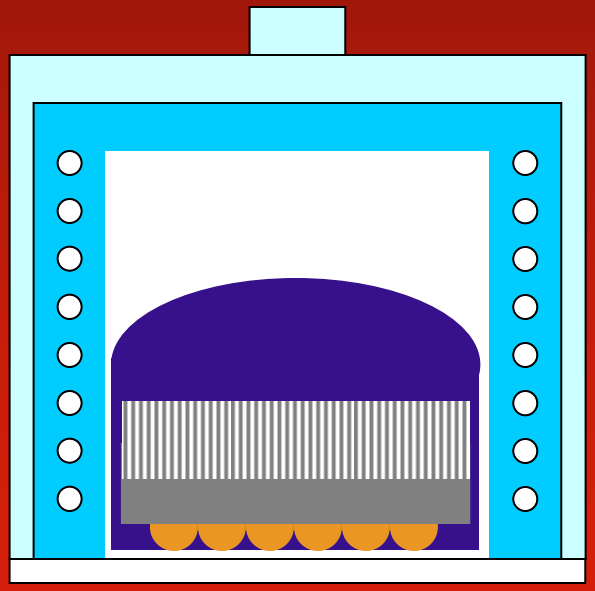


Feasibility Studies

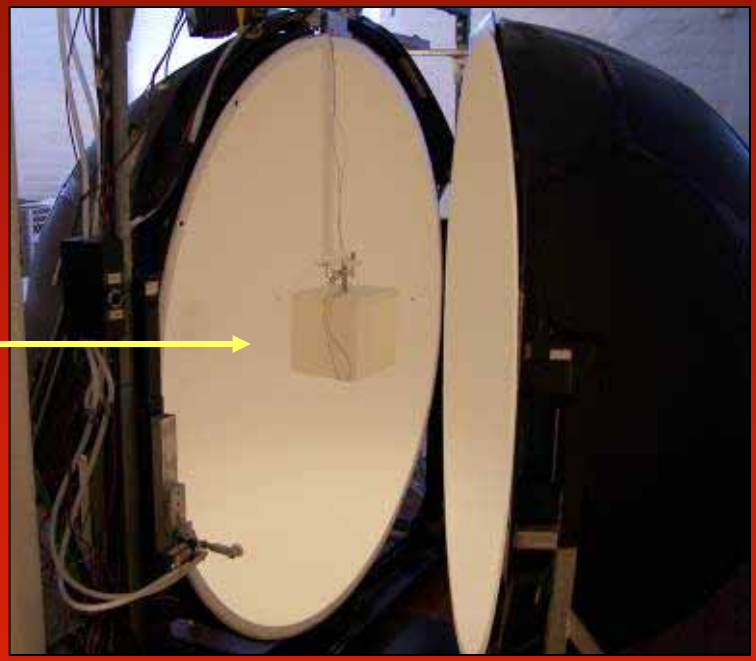
- To study the feasibility of the proposed concept, two pilot studies were conducted.
- Pilot study 1:
  - A prototype LED downlight was first set up inside an IC test box.
  - While operating the fixture inside the IC test box, Ts temperature was measured using a thermocouple.
  - Flux from the fixture was measured using the flux-o-meter.

Pilot Study #1

- Then the same LED fixture was placed inside the test enclosure with the heating elements, and was then placed inside an integrating sphere for measuring flux at the same Ts temperature.

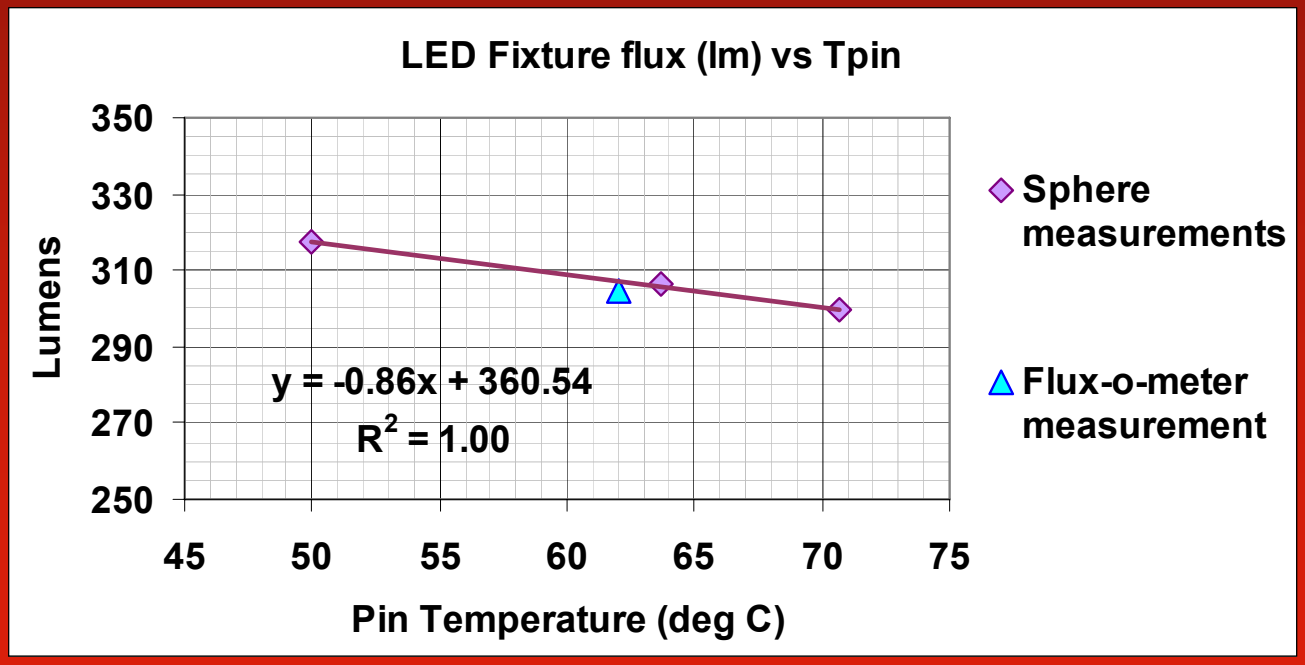


Test enclosure



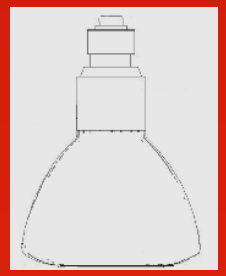
Pilot Study #1 – Results

- At pin temperature 62°C
  - Measured flux (Flux-o-meter): 304 lumens
  - Estimated flux from pin temperature: 307 lumens
- Results from the two setups matched within 1%



Pilot Study #2

- A commercial RGB LED PAR lamp was operated in the three environments—open air, Non-IC and IC—and the respective Ts temperature values were measured.
- Next, the same RGB PAR lamp was operated in the test enclosure inside the sphere, and measurements were taken at several Ts values.



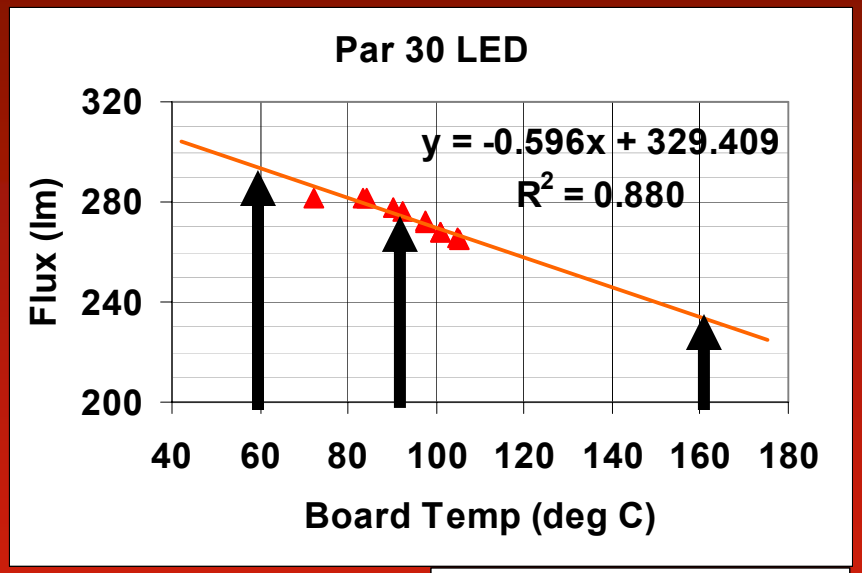
Ts IC ~ 160°C

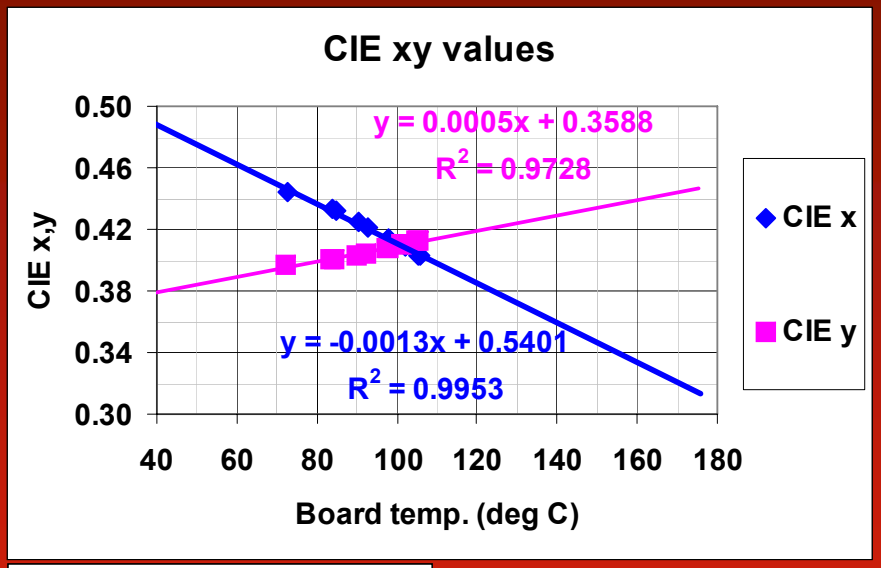
Ts Non-IC ~ 90°C

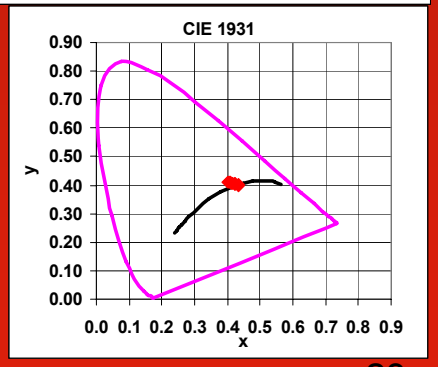
Ts Open-air ~ 60°C

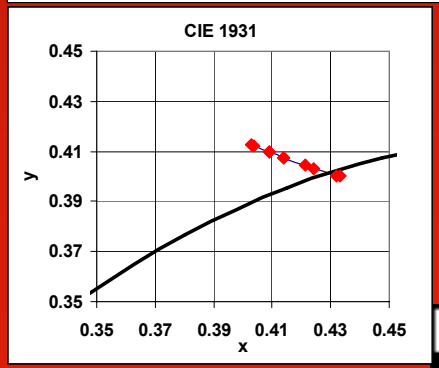
Pilot Study #2 – Results

- Knowing the Ts value in a given application, the PAR lamp, performance in that operating environment can be determined.









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Summary

- It is feasible to create test environments mimicking the actual environment where the fixtures would be used in order to obtain realistic performance data for a lighting system.
  - In the case of LED fixtures, by knowing the Ts values, the performance of fixtures and lamps in any operating environment can be measured.
  - Although shown for LED systems, a similar approach can be taken for CFLs and other light source technologies.

Under-cabinet Lighting

- The main objective here is to develop a test method that can be used for testing and comparing under-cabinet lighting systems
- Many commercial products for under-cabinet applications
  - Halogen
  - Fluorescent
  - LED

Testing and Evaluation

- Top performance criteria for end-users
  - Amount of illuminance on task area
  - Color of the light within the optical beam
  - System life when used in an application

- These are influenced by the luminaire design

Proposed Metric

- Application efficacy rather than source or fixture efficacy

- Method considers the application environment rather than the ideal environment for the lamp

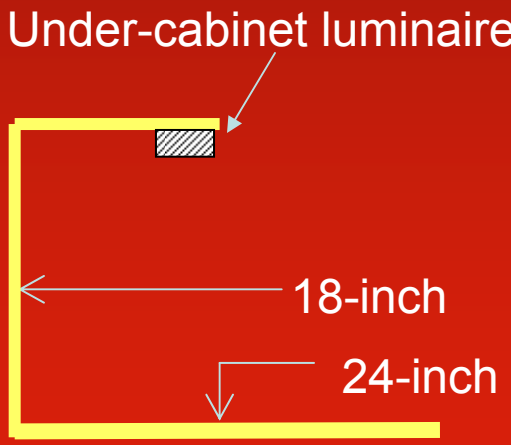
Proposed Method

- Calculate luminaire efficacy using near-field photometry
  - Small distance between UC light source & task plane calls for near-field photometry.
  - Amount of flux illuminating the task plane is the most useful, not all the flux that exits the luminaire.

$$\text{Application efficacy} = \frac{\text{Total lumens on the task}}{\text{Total fixture power}}$$

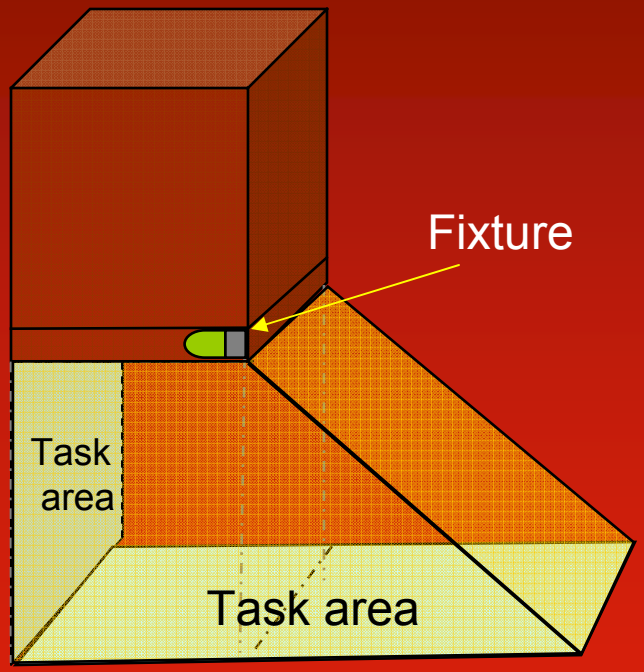
Proposed Apparatus

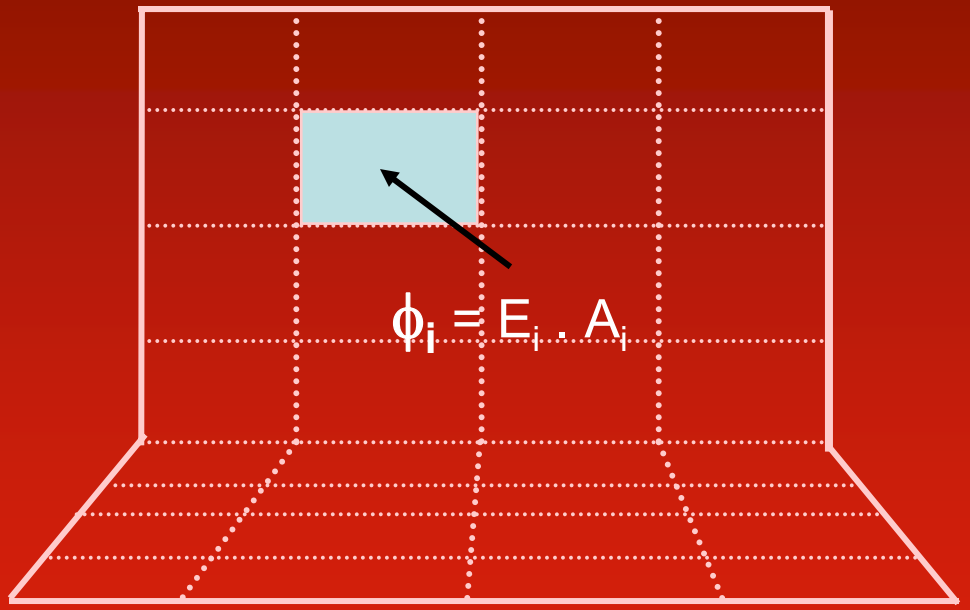
- Under-cabinet Testing Alcove
  - The proposed apparatus emulates the application environment
  - Plywood construction in common cabinet, backsplash, and counter sizes.
  - “Cabinet” length extends 12 in. beyond luminaire on each side.
  - Black counter top and back splash in the measurement area, with a grid for illuminance measurement



Proposed Test Method

- Measure, illuminance in each grid
- Calculate flux in each grid, and sum them all to obtain flux on the vertical surface and the horizontal surface.





$\phi v = \sum Ev \cdot Av$; $\phi h = \sum Eh \cdot Ah$

Application Efficacy = ϕ_T / W (lm/W)

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Summary

- For under-cabinet fixtures
  - Application efficacy is a more meaningful criterion for system comparison for energy use
    - Light where you need it
  - Near-field photometry is more relevant
- Application efficacy emphasizes directionality characteristics
- Some manufacturers already provide illuminance data in the grid format

Final Summary

- To make meaningful comparisons between products, performance metrics developed for lighting applications must be technology-independent.
- To obtain realistic performance data for a lighting system, the test environment must mimic the actual environment where it would be used.
- For task-lighting applications:
  - Application efficacy is a more meaningful criterion for system comparison
    - Light where you need it

Thank you

For more information please visit

http://www.lrc.rpi.edu/programs/solidstate/assist